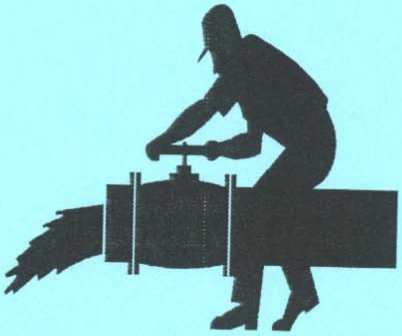
IRRIGATION

Best Management Practices For Agriculture in New Hampshire



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Acknowledgements

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Introduction and Purpose

The purpose of these Best Management Practices (BMPs) are to provide a set of principles and practices to guide agricultural operators toward the most efficient use possible of the water resources of New Hampshire. While it is acknowledged that irrigation as practiced by agriculture in New Hampshire, due to a short growing season and generally abundant rainfall, is usually limited to a small number of days and in some years may not be necessary, it is also recognized that the need for irrigation in times of drought most often coincides with periods of minimal stream flow. At times of drought the need for conservation and efficient use is most critical, however, in order to make most efficient use of the state's water resources, the practices included in this manual are recommended for water withdrawals for irrigation and other agricultural purposes at all times.

Best Management Practices for the use of irrigation water can help conserve and maximize the efficient use of our state's valuable surface and groundwater supplies. In addition, BMPs can help minimize surface and groundwater contamination. BMP's also help the agricultural producer to efficiently utilize precipitation and irrigation for profitable crop production by seeking to apply irrigation in a manner that stores water in the crop's active root zone and minimizes percolation of water below the root zone.

BMPs for irrigation are based on the implementation of the following management techniques in concert with a knowledge of site specific variables.

Management Techniques

- Schedule irrigations with appropriate amounts and frequency.
- Measure current soil water status, rainfall and irrigation water applied to a field.
- Balance rainfall and irrigation applications with crop water use.
- Design and maintain irrigation systems to prevent waste and for most efficient use.

Site Variables

- Soil type considerations.
- Slope
- Crop root zone and stage of growth water use
- Depth to groundwater

IRRIGATION SCHEDULING

Proper irrigation scheduling, based on timely measurements or estimations of soil moisture content and crop water needs, is one of the most important BMP's for irrigation management. A number of devices, techniques and computer aides are available to assist producers in determining when water is needed and how much is required (Table I).

Soil water can be measured using a variety of devices including:

- **Tensiometers**, which measure soil water suction;
- **Electrical resistance blocks** (also called gypsum blocks or moisture blocks), which measure electrical resistance that is related to soil water by a calibration curve;
- **Neutron probes**, which directly measure soil water;
- **Phene cells**, which are used to estimate soil water based on the relationship of heat conductance to soil water content, and;
- **Time domain reflectometers**, which can be used to estimate soil water based on the time it takes for an electromagnetic pulse to pass through the soil.

The appropriate device for any given situation is a function of the acreage of irrigated land, soils, cost and other site specific factors.

Irrigation scheduling uses a selected water management strategy to prevent the over-application of water while maximizing net return. In a sense, all irrigations are scheduled, whether by sophisticated electronic systems or simply by the farmer's hunch as to when water is needed. Experienced producers know how long it takes for crop stress to develop on their fields and are proficient at providing water when necessary. The difficulty lies in applying only enough water to fill the effective root zone without unnecessary deep percolation or runoff. Proper accounting for crop water use provides producers with the knowledge of how much water should be applied at any one irrigation event.

Table I. **Irrigation scheduling methods and tools**

Method	Tools or parameters used	Advantages/disadvantages
Soil moisture monitoring (Indicates when and how much to irrigate)		
Hand feel and appearance	Hand probe	Variable accuracy, requires experience
Soil moisture tension	Tensiometers	Good accuracy, easy to read, but narrow range
Electrical resistance tester	Gypsum block	Works over large range, limited accuracy
Indirect moisture content	Neutron probe/TDR	Expensive, many regulations
Gravimetric analysis	Oven and scale	Labor intensive
Crop canopy index (Indicates when to irrigate but not how much to apply)		
Visual appearance	Field observations	Variable accuracy
Water stress index	Infrared thermometer	Expensive
Water budget approach (No field work required, but needs periodic calibration since only estimates water use)		
Checkbook method	Computer/calculator	Indicates when and how much water to apply
Reference ET	Weather station data	Requires appropriate crop coefficient
Atmometer	Weather station data	Requires appropriate crop coefficient

Effective scheduling of irrigation requires an understanding of:

- Soil water holding capacity
- Current available soil moisture
- Crop water use or evapotranspiration (ET)
- Crop sensitivity to moisture stress at current growth stage
- Irrigation and effective rainfall received
- Availability of water supply
- Length of time it takes to irrigate a particular field

The decision to irrigate should be based upon an estimate of crop and soil water status, coupled with some indicator of economic return. Proper scheduling may allow producers to reduce the traditional number of irrigations, thereby conserving water, labor and plant nutrients. In some cases, the final irrigation of the season can be avoided through proper scheduling. This is especially advantageous from a water quality standpoint, because it is desirable to go into the off-season with a depleted soil profile. This leaves space for storage of precipitation in the crop root zone without unnecessary leaching or runoff.

Scheduling irrigation applications is often accomplished by using root zone water balance approaches. These methods use a "checkbook" or budgeting approach to account for all inputs and withdrawals of water from the soil. A simple mathematical expression can be written to illustrate this concept;

$$I + P = ET + Dr + Ro + (Oe - Ob)$$

where
I = irrigation water applied
P = precipitation
ET = evapotranspiration (soil evaporation + plant use)
Dr = drainage or percolation of water below the root zone
Ro = runoff
Oe = the water content expressed as a depth of water at the end of a time interval
Ob = the soil water content (depth) at the beginning of the time interval

The beginning soil water content (Ob) is generally estimated as field capacity if the root zone was fully wetted previously. Drainage (Dr) is estimated as the excess water applied above the field capacity depth. Precipitation is easily measured with rain gauges. The main unknown in the balance is ET. This information may be available through the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) or the University of New Hampshire's Cooperative Extension Service (CES). Producers should choose the scheduling method which best suits their needs and management capabilities. Regardless of the method used, some on-site calibration is required.

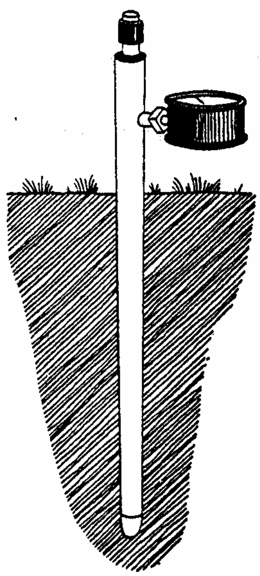


Fig. 1. Tensiometer

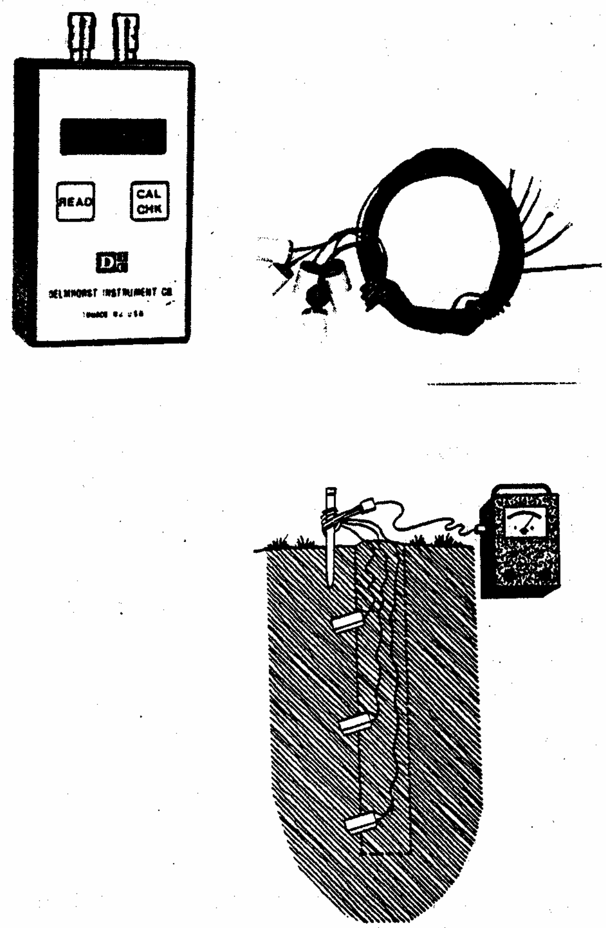


Fig. 2. Electrical resistance blocks

SOIL AND CROP PROPERTIES

Soil Characteristics

Soil characteristics which affect irrigation management include the water intake rate, available water holding capacity, and soil erosivity. Soil texture, organic matter content, soil structure, and permeability influence these characteristics and may limit producers' management and system options. For this reason, no one type of irrigation system is universally more efficient than another.

Producers should know the predominant soil type in each field receiving irrigation water. The available water-holding capacity should be used with the current depletion status to schedule irrigation. This soil information can be obtained from your local NRCS office or from county soils maps.

Table II. **Typical available water-holding capacity of soils of different texture**

Soil textural class	Inches of available water per foot of soil depth
Coarse sands	0.60 - 0.80
Fine sands	0.80 - 1.00
Loamy sands	1.10 - 1.20
Sandy loams	1.25 - 1.40
Fine sandy loams	1.50 - 2.00
Loam	2.20 - 2.50
Silty loams	2.00 - 2.50
Silty clay loams	1.80 - 2.00
Silty clay	1.50 - 1.70
Clay	1.30 - 1.50

Crop Characteristics

Crop characteristics influencing irrigation management options include crop water demand and effective root zone depth (Table III). Plants remove water from the soil by a process known as transpiration. Consumptive use refers to the amount of water transpired by the plant plus what is evaporated from the soil. It is known as ET (evapotranspiration). Accounting for crop ET between irrigations allows producers to determine how much water must be replaced in the soil profile.

Each crop has its particular periods of critical moisture needs, but in many crops (such as corn, beans, and peas) the most critical period is during or just after flowering. The flower development stage in these crops takes place in a more concentrated time period and meeting the moisture needs during this period is critical. These vegetable crops, along with tomato, peppers, eggplant and potato, and most fruit crops, also have high moisture needs during fruit or tuber development.

Crop root depth is primarily influenced by plant genetics, restrictions within the soil horizon, and the maturity stage of the crop (see Fig.3). However, deep watering at early growth stages can increase root depths thereby increasing drought resistance. Table III lists the soil depth to which mature crops derive the majority of their water needs. Irrigation water that penetrates below crop roots constitutes deep percolation and should be minimized.

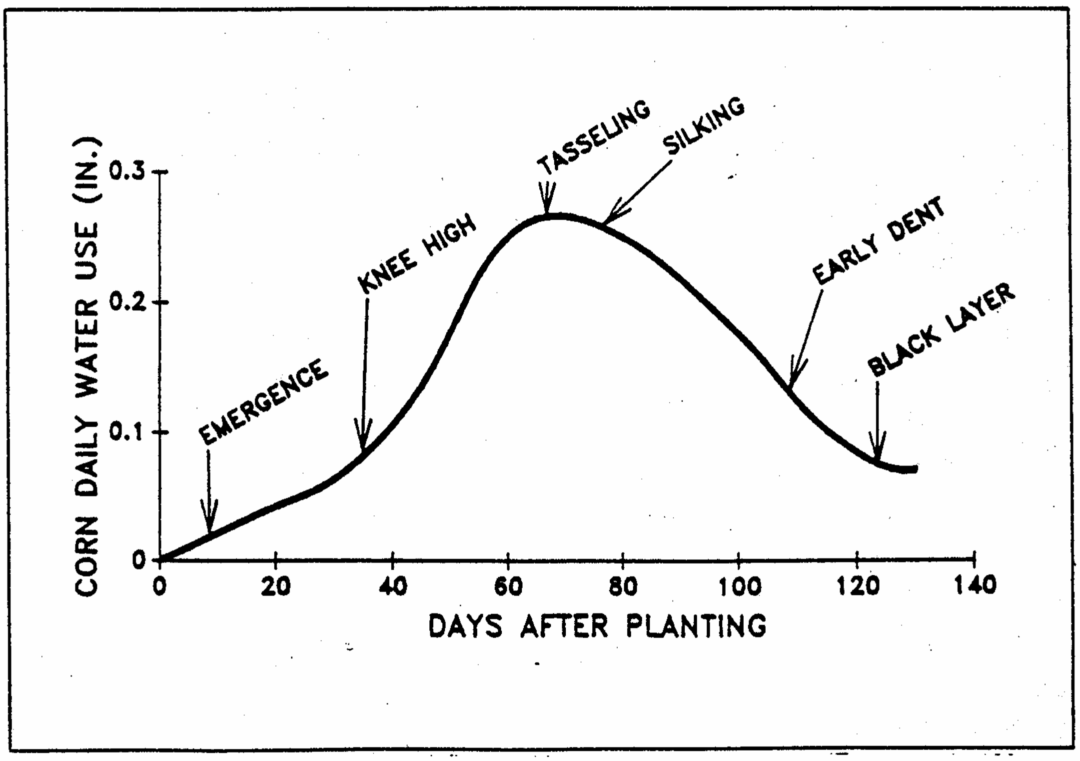


Fig. 3. Daily water use for field corn by stage of development

TABLE III.

Crop Grouping According to Depths of Moisture Extraction

I 6"

- Annual flowers
- Athletic fields (in use)
- Celery
- Grass sods - bluegrass (sod for sale)
- Lettuce
- Radishes
- Spinach

II 12"

- Athletic fields (not in use)
- Beets
- Broccoli
- Carrots
- Cauliflower
- Nursery stock
- Onions
- Parsnips
- Peas
- Strawberries
- Swiss chard
- Turnips

III 18"

- Beans
- Blueberries (wild)
- Cabbage
- Cucumbers
- Eggplant
- Ladino clover
- Peppers
- Potatoes
- White Clover

IV 24"

- Asparagus
- Birdsfoot trefoil
- Blueberries (cultivated)
- Brome
- Cantaloupe
- Corn
- Grapes
- Orchardgrass
- Pumpkins
- Sorghum, millet
- Soybeans
- Squash
- Timothy
- Tomatoes
- Watermelon

V 30"

- Alfalfa
- Orchards

IMPROVED IRRIGATION TECHNOLOGIES

A number of technologies have been developed to apply water more uniformly without excessive waste. Among these are systems such as low-pressure center pivot, low-energy precision application, surge, and micro-irrigation. These improvements may require capital, energy, or increased management costs.

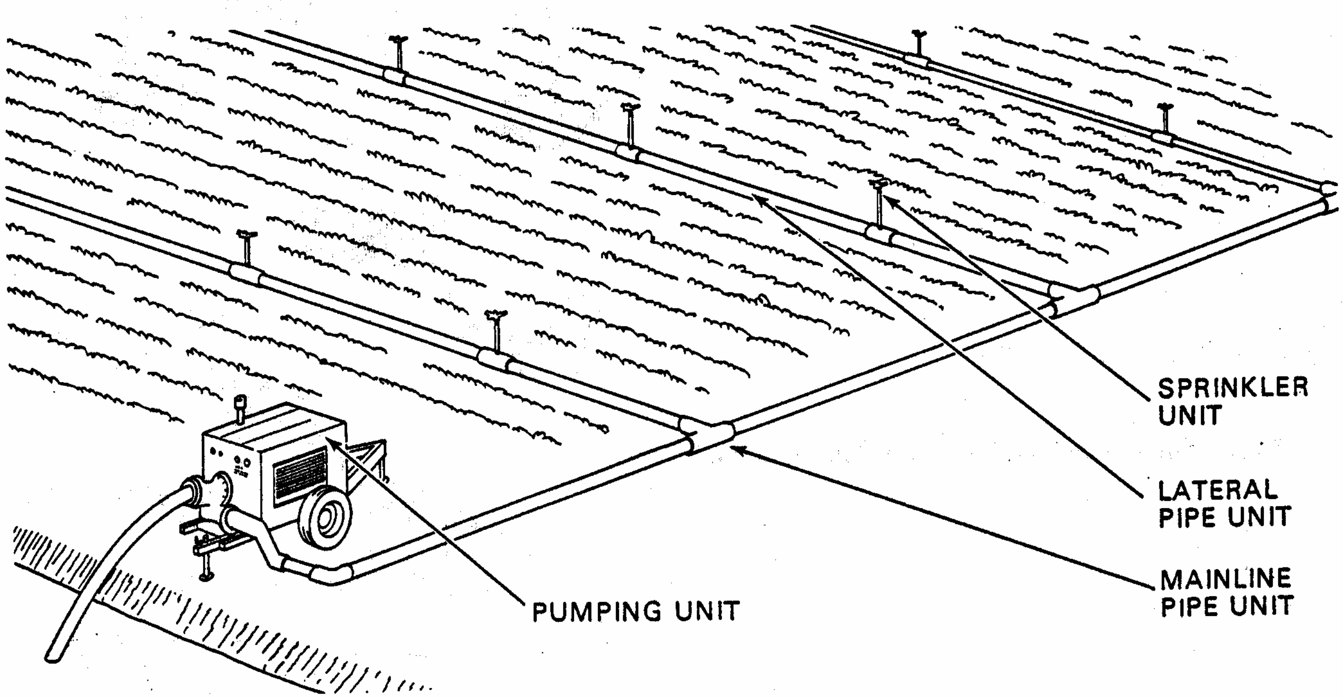
Table IV. **Approximate efficiency of various irrigation application methods**

	Range	Mean
	% efficiency	
Conventional furrow	25-60	40
Surge	30-80	60
Sprinkler	60-95	75
Drip	80-95	90

Application efficiencies can vary widely among irrigation methods depending upon soil, crop, topography, climate, and management. Irrigation efficiency can be expressed as the ratio of water needed for crop production, to the volume of water diverted for irrigation. Field level irrigation efficiency for a single application can be calculated as:

Ea(application efficiency)=volume of crop evapotranspiration/volume water applied to field.

Fig. 4. Components of a typical sprinkler application system



Micro and Drip Irrigation

Micro-irrigation systems such as micro-sprinklers, low flow trickle or drip irrigation offer the advantage of precise nitrogen and irrigation water management. These systems are being used profitably in orchards, vineyards, and high value row crops. The higher initial cost of installation and the potential for clogging with poor quality water present obstacles for some producers. However, the high uniformity, efficiency and low labor requirements offer significant advantages to irrigators with limited available water supplies. Those advantages include the following:

- Adaptable to small, odd shaped fields or those with uneven topography.
- Less volume of water per unit of time is required.
- Precise water application offers reduced evaporation, reduced or eliminated deep percolation and runoff, and uniform delivery of water to crops.
- The possibility of precise fertilizer and chemical application thus reducing nitrogen losses and chemical costs.
- The system can be automated thereby reducing labor inputs.

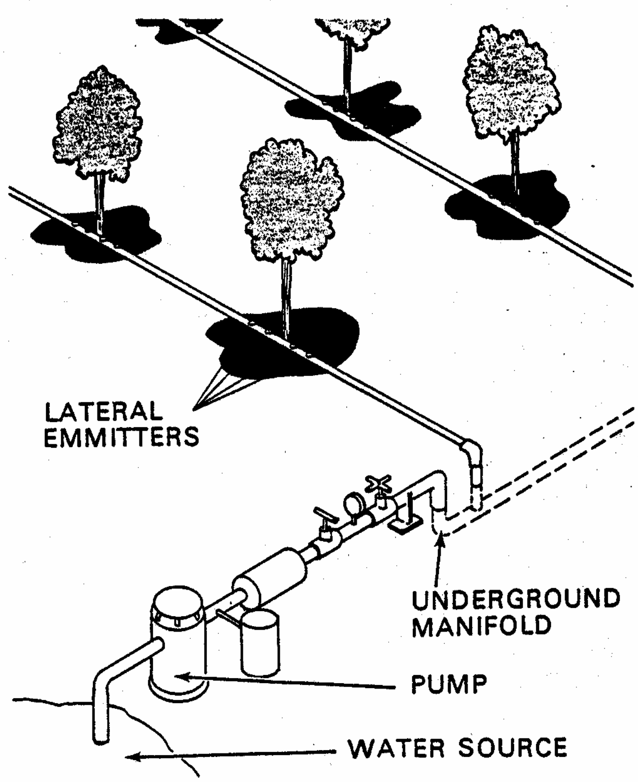


Fig. 5. Surface application by the trickle method

MANAGING WATER APPLICATION

Sprinkler system operators need to adjust application rates according to the soil intake rate and slope. Soils vary significantly in water infiltration rate, ranging from 2.0 to 0.2 inches per hour. It is important to have an idea of the amount of water necessary to bring a particular soil type to field capacity. Field capacity is the amount of water a given soil will hold following saturation, and drainage has ceased and capillary adjustments have taken place).

High application rates, in addition to being wasteful of water and the energy required to deliver it, can result in surface runoff or in ponding and deep percolation losses, resulting in plant nutrients being transported out of the root zone. Low application rates can be inefficient due to excessive evaporation.

Proper sprinkler system design and maintenance is essential to achieve high efficiencies with minimal runoff or deep percolation. Water supply lines, connections, valves and pumps should be checked frequently for leakage.

Managing for Water Conservation

In order to be economically viable agricultural water users are naturally intent on producing the highest quality crop with the lowest possible cost input. That purpose need not conflict with sound water conservation practices. Crop irrigation and other farm water uses such as livestock watering, dairy sanitation activities, and fruit and vegetable cleaning and processing can all be accomplished efficiently by incorporating some of the following techniques.

- Measure the quantity of water used for irrigation. Use flow meters (see Figs. 6 & 7) or gauged water pans for sprinkler systems. Water application volumes should be recorded and referred to in subsequent years to assure uniform and consistent water distribution.

- For cleaning operations install faucet aerators, flow restrictors and high pressure-low flow devices.

- Where feasible, collect wash and rinse water for reuse. Consider utilizing grey water and waste water from other sources. Investigate the regulations that might effect the reuse of waste water.

Managing to Conserve Soil-Water

Utilizing certain conservation tillage techniques and soil management practices can reduce the waste of water resources and lessen the quantity of water needed to produce profitable crops. Consider utilizing the following practices or materials:

- Increase the capacity of the soil to store moisture by incorporating organic materials. Compost, manure and other suitable organic wastes when added to soil can significantly improve soil water holding capacity. Winter cover crops that are turned under in the spring will also help maintain higher organic matter content of the soil.

- The use of cover crops in winter can also increase soil organic matter content. Cover crops can also reduce evaporation when used during the growing season.

- Conservation tillage practices, such as no till can minimize soil water losses due to evaporation and runoff. Low till or no till techniques also increases water infiltration and reduces surface runoff.

- Surface mulches of organic (bark, peat) or synthetic (plastic) materials around horticultural crops can significantly reduce the need for irrigation. Suitable growing season cover crops between the rows can also reduce surface evaporation.

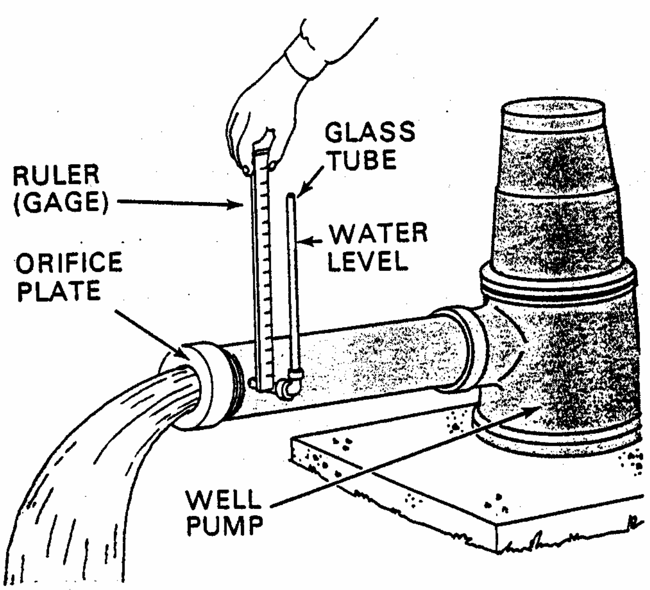


Fig. 6. An orifice plate for measuring water flow in pipes

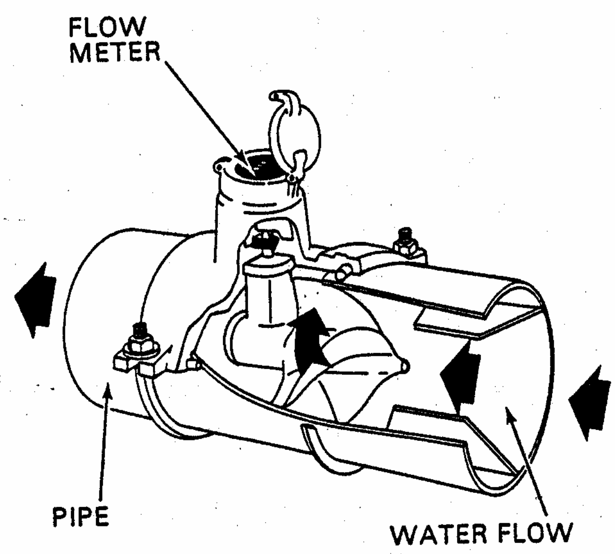


Fig. 7. A flowmeter used for measuring flow from a well

Summary

To maximize irrigation water efficiency and avoid waste or water quality impacts, producers should determine:

- When irrigation water should be applied
- How much water is needed to satisfy crop requirements
- Application rate required to apply the correct amount of water.

This information should be used by the irrigator to select irrigation methods and BMPs to conserve water. All BMPs are not appropriate for every field and irrigation system. Producers must evaluate agronomic and economic factors to determine the feasibility of installing upgraded systems or management practices. It may be advisable to obtain professional help in evaluating options for improving irrigation systems.

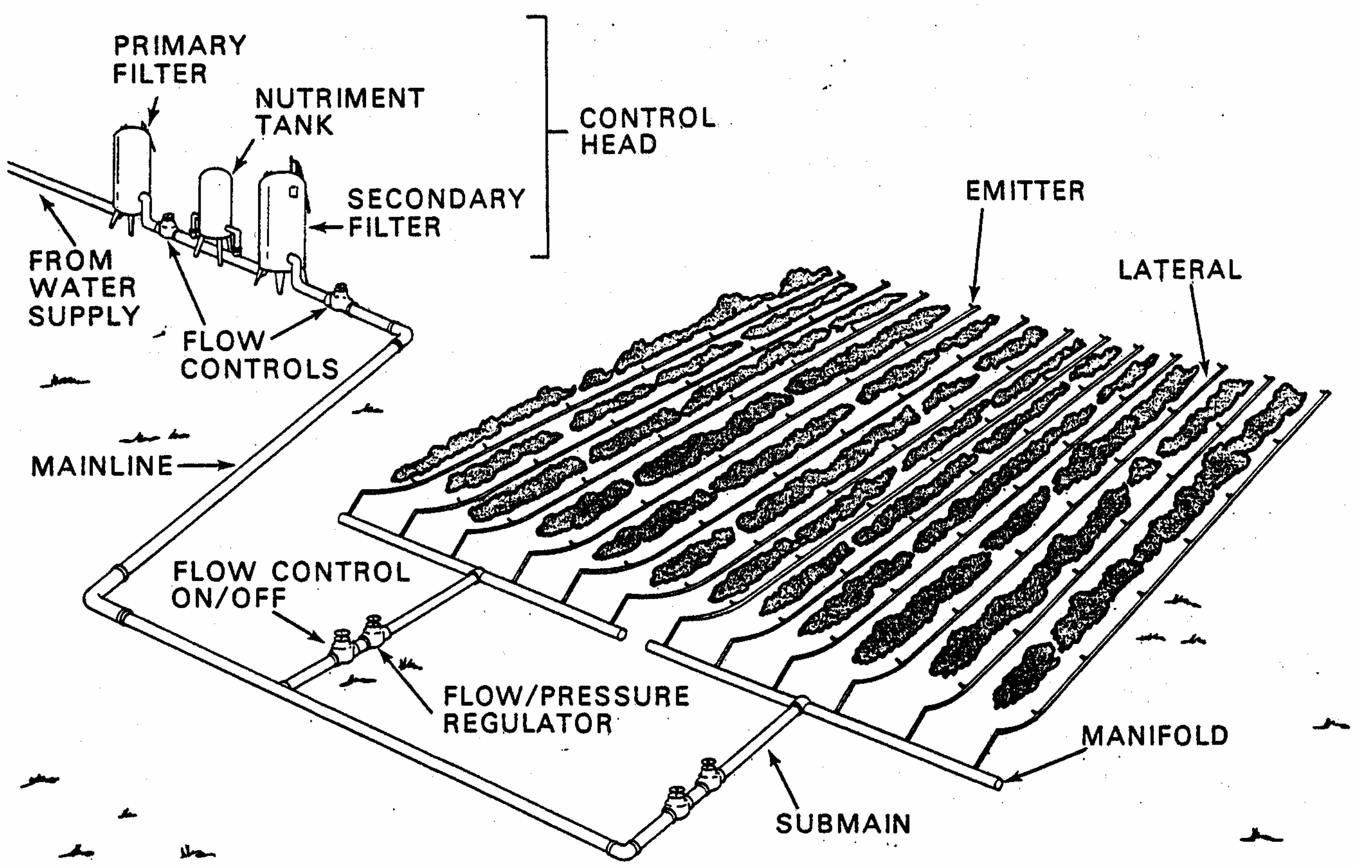


Fig. 8. Basic units of a trickle application system

IRRIGATION BEST MANAGEMENT PRACTICES

General Irrigation BMPs:

1. Monitor soil moisture by the feel method, tensiometers, resistance blocks, or other acceptable methods before and after each irrigation.
2. Schedule irrigation according to crop needs, soil water depletion, and water availability, accounting for precipitation. Apply only enough water to fill the effective crop root zone.
3. Evaluate the efficiency of the total irrigation system from the pump to the point of delivery. Upgrade irrigation equipment to improve delivery and application efficiency where feasible.
4. Monitor irrigation application and uniformity of water applied.
5. Time irrigations to individual crop needs to eliminate unnecessary applications. Calculate the date of the final irrigation of the season to ensure the soil profile is largely depleted by crop harvest.
6. Contact a qualified professional to help schedule irrigation and determine the application efficiency of your system, if necessary.

Sprinkler Irrigations BMPs:

7. Minimize deep percolation below the crop root zone on sprinkler irrigated fields by applying water according to crop evapotranspiration and soil moisture status.
8. Minimize surface runoff and increase uniformity on sprinkler irrigated fields by decreasing application depth or by changing nozzle and pressure configuration, height, or droplet size as appropriate.
9. Maintain sufficient surface residue to reduce overland water flow and increase moisture intake rate. Where practical, follow soil conservation practices such as minimum tillage or contour planting to reduce erosion of soil sediments. Plant grass filter strips on the downhill side of any highly erodible field to filter nutrients or chemicals from runoff.
10. Test systems periodically for depth of application, pressure and uniformity.

Micro-Irrigation BMPs:

11. Design layout of drip tube or tape systems with consideration of the crop to be irrigated, and the field contour and topography.
12. Emitter spacing, pressure and flow need to meet the crop's water requirements and soil properties.
13. Manage filters, tubes and emitters to avoid leaking or plugging. Some fertilizers and water supplies may lead to chemical precipitation in tubes and emitters. Seek water quality analysis and manufacturer's technical advise before beginning.

WATER USER REGISTRATION AND REPORTING PROGRAM

Authorized by Chapter 402 Laws of 1983, the water user registration and reporting program went into effect in the summer of 1987. The objective of the program is to gather accurate data on the major uses of the State's water and the specific demands placed upon individual aquifers, streams and rivers. To accomplish this objective, all water use which exceeds 20,000 gallons per day, averaged over a 7-day period, or exceeds 600,000 gallons during any 30-day period must register with the NH Department of Environmental Services (NHDES). Use of water is broadly interpreted to mean withdrawal of water from a source and/or return of water to the environment. Withdrawals for irrigation use are exempt if the usage does **not** exceed 140,000 gallons per week, or the area irrigated does **not** exceed 5 acres.

The registration process requires the water user to identify the name, address, and general location of the water use activity, including the name of a contact person. Information is also required on the type of use, identification of the source and destination of the water and the method of measuring usage. Existing water users as of June 30, 1987 must have been registered with NHDES by December 28, 1987. New water users must register within 30 days of commencement of use. Once registered, the user must measure the amount of water used.

Additional information on the program and copies of registration forms can be obtained by writing to the NHDES - Water Division, PO Box 2008, 64 N. Main Street, Concord, NH 03302-2008 or calling (603) 271-4086.

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US EPA, Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, January 1993.

ADDITIONAL INFORMATION

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GLOSSARY

Backflow prevention device: A safety device used to prevent water pollution or contamination by preventing flow of water and/or chemicals in the opposite direction of that intended.

Chemigation: The addition of one or more chemicals to the irrigation water.

Check valve: A device to provide positive closure that effectively prohibits the flow of material in the opposite direction of normal flow when operation of the irrigation system plumbing plant or injection unit fails or is shut down.

Diversion: A channel, embankment, or other man-made structure constructed to divert water from one area to another.

Field capacity: The soil-water content after the force of gravity has drained or removed all the water it can, usually 1 to 3 days after rainfall.

Infiltration: The penetration of water through the ground surface into subsurface soil.

Irrigation: Application of water to lands for agricultural practices.

Irrigation scheduling: The time and amount of irrigation water to be applied to an area.

Lateral: Secondary or side channel, ditch or conduit.

Percolation: The downward movement of water through the soil.

Permanent Wilting Point: The soil water content at which healthy plants can no longer extract water from the soil at a rate fast enough to recover from wilting. The permanent wilting point is considered the lower limt of plant-available water.

Permeability: The quality of a soil horizon that enables water or air to move through it; may be limited by the presence of one nearly impermeable horizon even though the others are permeable.

Plant-available water: The amount of water held in the soil that is available to plants; the difference between field capacity and the permanent wilting point.

Return flow: That portion of water diverted from a stream that finds its way back to the stream channel either as surface or underground flow.

Root zone: The part of the soil tht is, or can be, penetrated by plant roots.

Soil water depletion volume: The amount of plant-available water removed from the soil by plants and evaporation from the soil surface.

Surface water: All water whose surface is exposed to the atmosphere.

Tailwater: Irrigation water that reaches the lower end of a field.

Water table: The upper surface of the ground water or that level below which the soil is saturated with water; locus of points in soil water at which the hydraulic pressure is equal to atmospheric pressure.